Artificial Lift Design of Mishrif Formation in Nasiriyah Oil Field

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Abstract:

The possibility of improving the oil production rate for Mishrif formation in Nasiriyah oil field, located in Thi-Qar Governorate – southern province of Iraq, proposed in this paper. Electrical submersible pump (ESP) and gas lift techniques were applied to one well (NS-Y) in the studied reservoir. Firstly, the mathematical model has been built and validation has been done using PIPESIM software in order to select the best correlation (Duns & Ros correlation) for the pressure gradient calculation in the wellbore. The effect of decreasing reservoir pressure and increasing water cut on production rate has been studied through the evaluation of the well performance. The production rate was decreased to 1917 STB/D when reservoir pressure reached to 2750 psi, and flow rate decreased to 1210 at water cut 60%. Therefore, the artificial lift techniques were applied to increase the oil production rate. The result showed that Gas lift system contributed to increase production rate to (3198) STB/D at reservoir pressure equal to 2750 psi, while using the ESP system improved oil production rate to (2800) STB/D at reservoir pressure 2750 psi. The results also showed that gas lift system contributed to increase production rate to (3805) STB/D at water cut 60% and ESP raised the production rate to 3087 STB/D at water cut 60%. The comparison between them showed that the gas lift technique gave the highest production rate at different reservoir pressure and water cut.

تصميم منظومة الرفع الصناعي لطبقة المشرف في حقل الناصرية النفطي

الخلاصة:

ان إمكانية تحسين معدل انتاج النفط لطبقة المشرف في حقل الناصرية النفطي الذي يقع في محافظة ذي قار جنوب العراق تم تناولها في هذه الدراسة. حيث تم استخدام تقنيات الرفع بالغاز والمضخات الكهربائية الغاطسة في البئر(NS-Y) التابع للحقل المختار لهذه الدراسة. تم بناء موديل

رياضي أولا ومن ثم عمل مطابقة لغرض اختيار أفضل معادلة تصحيح لغرض حساب تدرج الضغط خلال عمود البئر حيث كانت معادلة (Duns & Ros)) هي الأفضل. كذلك تم عمل تقييم لأدائية البئر لغرض معرفة تأثير انخفاض الضغط المكمني وارتفاع نسب القاطع المائي على معدل انتاج النفط لهذا البئر. حيث أظهرت النتائج نقصان معدل الإنتاج من 3016 الى 1917 برميل قياسي باليوم عند وصول الضغط المكمني الى 2500عقدة/انش. وكذلك نقصان معدل الإنتاج الى 1210 برميل قياسي عند ارتفاع نسبة القاطع المائي الى 60%. بعد تصميم منظومة الرفع الصناعي لغرض زيادة الإنتاج اظهرت النتائج ان منظومة الرفع بالغاز ساهمت في زيادة معدل الإنتاج الى 3198 برميل قياسي باليوم عند ضغط مكمني 2500عقدة/انش، في حين ان المضخة الكهربائية الغاطسة ساهمت في زيادة الإنتاج الى 2800 برميل قياسي باليوم عند ضغط مكمني 2500عقدة/انش. كذلك بينت النتائج ان منظومة الرفع بالغاز ساهمت في زيادة معدل الإنتاج الى 3805 برميل قياسي باليوم عند وصول نسبة القاطع المائي الى 60% في حين ان المضخة الكهربائية الغاطسة ساعدت على وصول الإنتاج الى 3087 برميل نفط قياسي باليوم عند وصول نسبة القاطع المائي الى 60%. أظهرت المقارنة بين النتائج ان منظومة الرفع بالغاز تعطي معدلات انتاج اعلى مقارنة مع المضخة الكهربائية الغاطسة عند ظروف مختلفة من نسب القاطع المائي والضغط المكمني لهذا البئر.

Introduction:

There are a number of oil wells, can flow naturally depending on the reservoir energy in the first life of production. After a period of production, the flow rate decreases until it is not possible for natural flow to continue. In order to maintain production for as long as possible, new methods were developed to resume or increase production. Artificial lift represents the one of these methods, which used when decreasing reservoir pressure and the well wouldn´t is able to lift fluid up to the surface **[1]**. Approximately 50% of wells need artificial lift systems. The commonly used method is artificial lift **[2]**. The most used methods in Iraqi oil fields are Gas lift and Electrical Submersible Pump, where the Gas lift method takes place through injection of a specific amount of compressed gas in the annular between casing and production tubing, which works by reducing the density of liquid in wellbore and lightening the hydrostatic column. This helps to raise the fluid to the surface, Gas lift is utilized in one of the two ways: (1) continuous gas lift by continuous gas injection into annular between the production tubing and casing (2) intermittent lifting by rapid injection of very large quantities of gas into the tubing, causing a slug of fluid in the tubing to be carried to the surface. The valve then closes, awaiting another column of fluid to build in the tubing **[3]**. The Electric submersible pump ESP use multiple-stage centrifugal pump with electric motor in the base of tubing and attached to a power source by cable. All these parts work together with lifting the fluid to the top **[4].** In this study Mishrif Formation in Nasiriyah Oil Field was selected to build a gas lift and ESP models. This field is located in the south of Iraq in the Thi-Qar governorate about (38) KM northwest of the Nasiriyah center **[5].**

Mathematical models:

A Mathematical model used to simulate fluid flow for the system. It contains complete information on the well, including wellbore construction, downhole equipment and artificial lift equipment. This model has been developed based on the available data from well completion reports as shown in Table (1).

Table (1) well depth and perforation intervals

Well name	Well depth (m)	Tubing depth (m)	Perforation intervals, (m)	Middle perforation, (m)
NS-Y	2039	1910	1995 –2037	2016

Fluid model:

This model is created by inserting fluid properties and then calibrate PVT data depending on the reports of the physical and thermodynamic properties of the oil (PVT data).

Pressure gradient matching:

The data matching task has been used to select the suitable flow correlations for the pressure drop and heat transfer calculations in the wellbore. Measured flow data available in (Production Log Interpretation Report) has been used Table (2). This data has been inserted in Survey data catalog of PIPESIM. The next step is to run data matching and choose the appropriate correlation among the correlations available in PIPESIM. The selection of the correlation is based on the optimal flow rate should give the lowest error ratio for the measured flow rate. The best flow rate gives the lowest value of (RMS).

Table (2) PLT data for pressure gradient.

Well name	Well head Pressure, psi	Well head Temperature, F	Test oil Flow rate STB/D	Depth m	Pressure, psi	Temperature, F
NS-Y	490	70	3106.8	1995	2397.2	164.94
				2010	2418.7	165.74
				2025	2436.8	166.58
				2023	2443.4	166.79

Matching results showed that Dun & Rose was the best fit for well NS-Y as shown in Figure (1). A comparison was made between the correlations should that results for calculating the optimized flow rate Table (3).

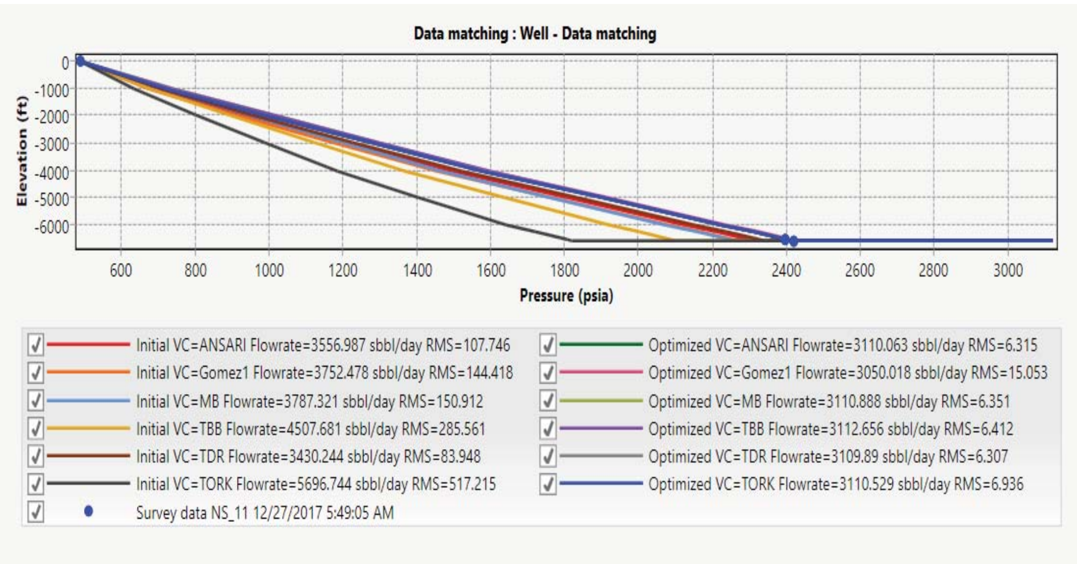

Fig. (1) Optimized flow rate match for well (NS-Y).

Table (3) Flow rate correlation comparison for well (NS-Y).

Correlation	Test liquid flow rate, STB/D	Calculated liquid flow rate, STB/D	Error %	RMS
Ansari	3106.84	3110.06	0.103	6.315
Gomez	3106.84	3050	-1.8	15
Mukherjee&Brill (baker jardine)	3106.84	3110.88	0.13	6.35
Biggs & Brill original	3106.84	3112.65	0.18	6.4
Duns & Ros (Tulsa)	3106.84	3109.89	0.09	6.307
Orkiszewski (Tulsa)	3106.84	3110.52	0.11	6.93

Nodal analysis and bottom hole pressure (P_{wf}) match:

After selecting the appropriate correlation for the well, a nodal analysis has been built which represent the relationship between vertical lift performance curve (VLP) and inflow performance relation curve (IPR), as shown in Figure (2). PIPESIM Software calculates the values of liquid flow rate and bottom hole pressure (P_{wf}) from the intersection point between the curves of (VLP) and (IPR). A good matching between the calculated P_{wf} (2421.49 psi) by using nodal analysis and measured P_{wf} (2424 psi) achieved with the error of 0.084%, see Table (4).

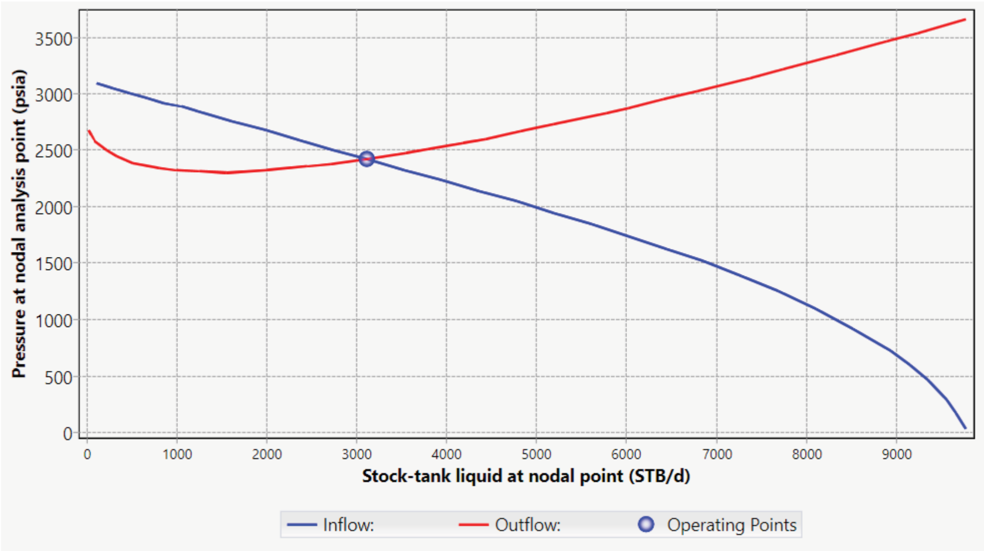

Fig. (2) Nodal analysis for well (NS-Y)

Table (4) Bottom hole pressure match for well (NS-Y)

Well name	Measured P_{wf}, psi	Calculated P_{wf}, psi	Error %
NS-Y	2424	2421.49	0.084

Well performance with the reduction of reservoir pressure:

Evaluation of well performance was considered using Nodal analysis (inflow sensitivity) by evaluating the effect of reduction of reservoir pressure on production flow rate for the well. The result showed that the production rate of well (NS-Y) reached 1917 STB/D when reservoir pressure decreased to 2750 psi, as shown in Table (5) and Figure (3). The value of bubble point pressure was 2105 psi.

Table (5) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, WC= 0, well head pressure = 490 psi, (natural flow)

Reservoir pressure, (Psi)	Liquid flow rate, (STB/Day)	Bottom hole pressure, (Psi)
3120.8	3109	2421
3050	2897	2398
2950	2594	2367
2850	2266	2340
2750	1917	2319

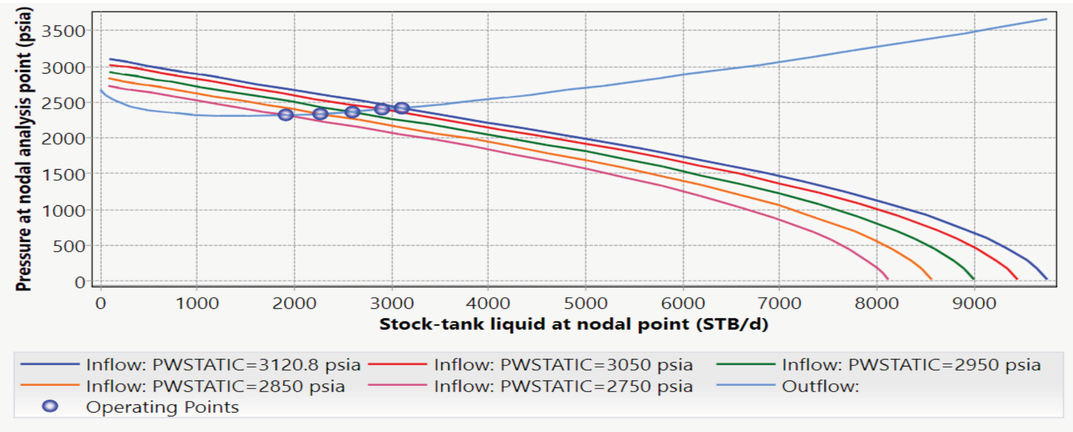

Fig. (3) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi, WC = 0%, well head pressure = 490 psi

Well performance with the increase in water cut:

As the water cut increases to 60%, the production rate reaches to 1210 STB/D. Table (6) shows that the liquid flow rate and bottom hole pressure for different rates of water cut. The values of Nodal pressure against nodal point are shown in Figure (4).

Table (6) Summary Results well (NS-Y) at WC= (0 – 60%) , well head pressure = 490 psi, (natural flow)

Water cut %	Liquid flow rate (STB/Day)	Bottom hole pressure (psi)
0	3109	2421
10	2961	2455
20	2735	2506
30	2464	2566
40	2129	2642
50	1717	2734
60	1210	2848

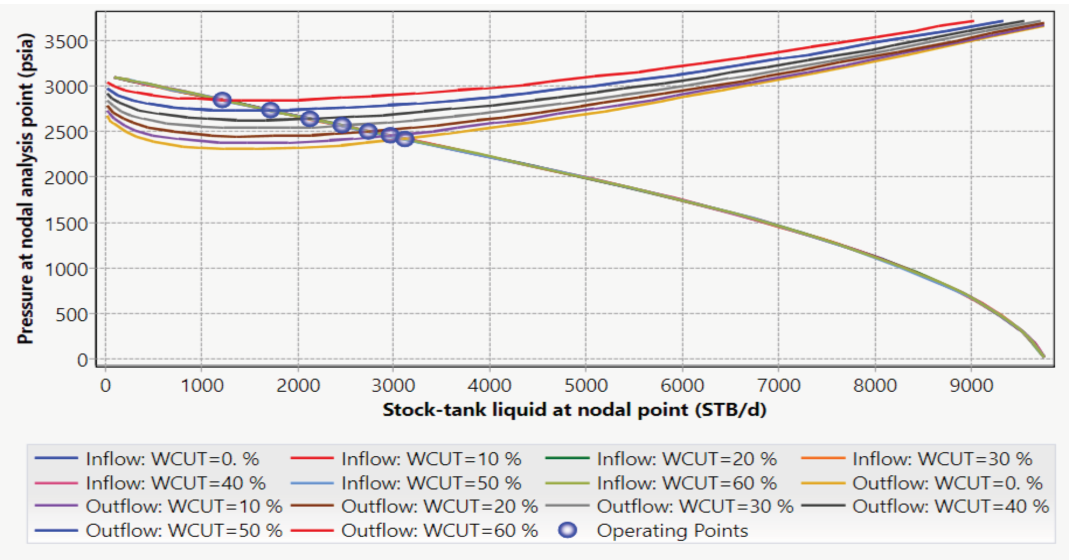

Figure (4) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = 3120.8 psi, WC = 0%,- 60%

Gas lift design:

The objective of this work is to find the best location for unloading valves and operating valves for the gas lift plant.

Determine optimum surface injection pressure and Optimum gas injection rate:

From a gas lift response simulation in PIPESIM, the well performance under gas lift with the surface injection pressure (casing head pressure, CHP) and target injection gas rate (Qgi) have been determined. The ranges of sensitivity data for gas lift response contain ten values for target injection gas rate and three values for surface injection pressure; therefore, the sensitivity was repeated twice for each well in order to take more values of (CHP). The results of gas lift response in PIPESIM for well (NS-Y) can be seen in Table (7) and Figures (5 and 6), which explained the optimum gas injection rate of 3MMSCF and optimum surface injection pressure of 1800psi.

Table (7) Summary Results well (NS-Y) at a gas injection rate (1 – 10) MMSCF, surface injection pressure (1000 – 2750) psi

Qgi MMSCF/D	QL@ CHP= 1000 psi	QL@ CHP= 1500 psi	QL@ CHP= 1750 psi	QL@ CHP= 2000 psi	QL@ CHP= 2500 psi	QL@ CHP= 2750 psi
1	3117	3486	3611	3668	3669	3669
2	3145	3683	3861	3920	3921	3921
3	3123	3724	3948	4010	4011	4011
4	3090	3686	3963	4031	4032	4033
5	3057	3635	3920	4007	4007	4008
6	3023	3576	3859	3960	3960	3961
7	2989	3516	3794	3907	3907	3908
8	2957	3462	3729	3852	3853	3854
9	2922	3407	3664	3799	3799	3800
10	2886	3357	3607	3747	3748	3749

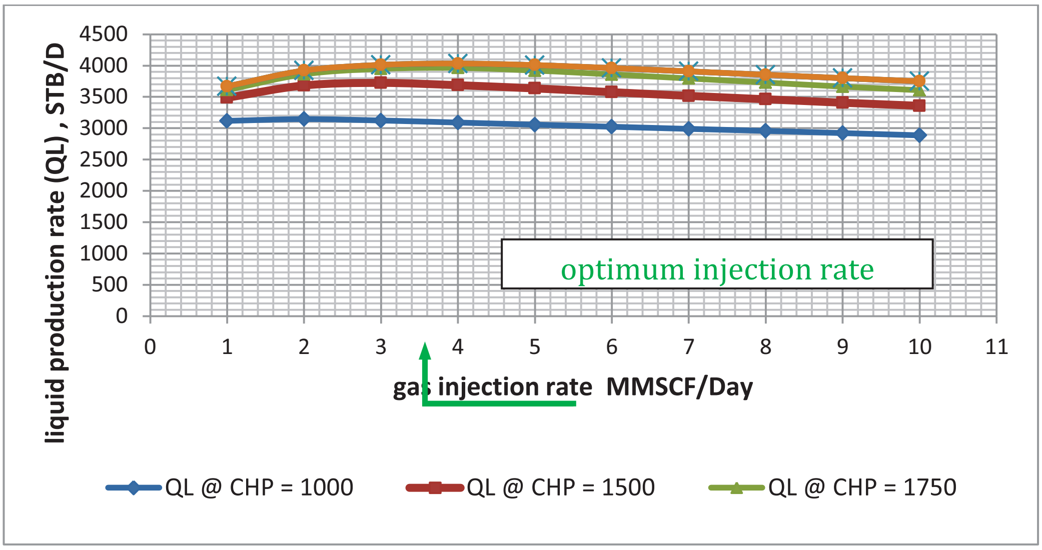

Fig. (5) Optimum gas injection rate of well (NS-Y) at gas injection rate (1 – 10) MMSCF, surface injection pressure (1000 – 2750) psi

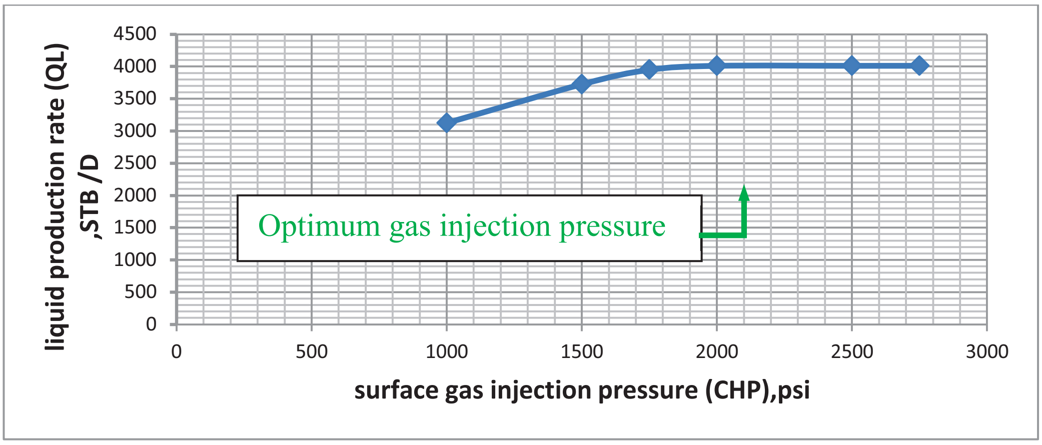

Fig. (6) Optimum surface injection pressure (CHP) of the well (NS-Y) at a gas injection rate (3) MMSCF, surface injection pressure (1000 – 2750) psi.

Gas Lift valves Installation design

The objective of the valve design is to determined position of the process and Unloading Valves, which depends on the gas injection pressure to calculate the Opening and closing pressures for gas lift valves. Figure (7) showed the results of well (NS-Y) as listed in Table (8).

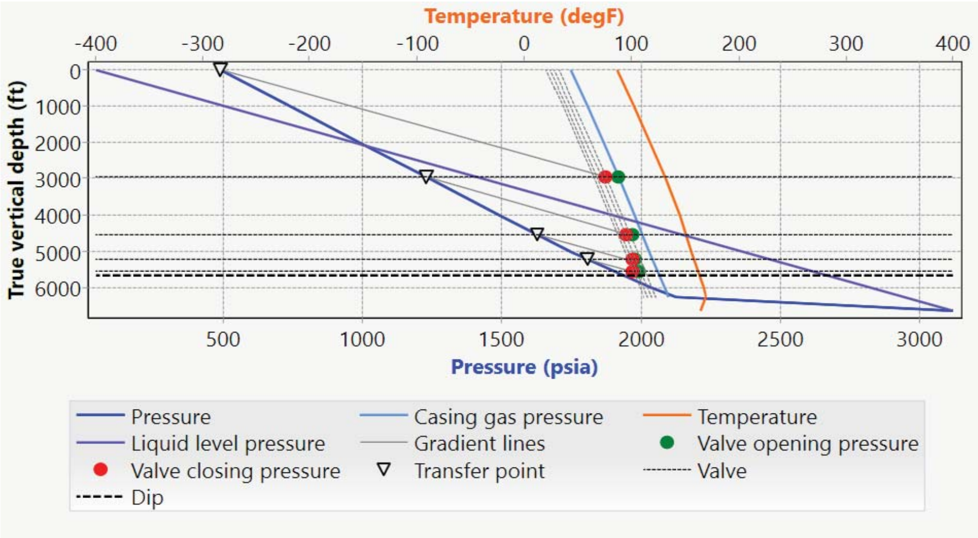

Fig. (7) Gas lift valves design for well (NS-Y)

Table (8) Gas lift valve design results for well (NS-Y)

Parameters	Valve 1	Valve 2	Valve 3	Valve 4
Measured Depth (m)	946	1434	1660	1761
Series	R20	R20	R20	R20
Port size (inches)	0.25	0.25	0.25	0.5
Production pressure psi	1281.7	1673.8	1868	1958
Unloading liquid rate, (STB/D	4264	3283	2319	3914.6
Valve opening Pressure, psi	1984.7	2038.3	2053.4	2075.5
Valve closing pressure, psi	1938	2014	2041.2	2045
Test rack opening pressure, psi	1779.9	1770.5	1763	2211.8
Valve temperature (F)	127.7	149.3	158	161.9

Electrical Submersible Pump Design:

Electrical Submersible Pump (ESP) Design task in PIPESIM can be used to select suitable ESP from the database and performs necessary calculations to determine the number of stages required to achieve a target flow rate under given well, fluid and operating conditions. Multiple operations are performed as part of the well's ESP design to calculate and report well performance before and after an ESP is installed. The important parameters for ESP design are.

Pump depth: The depth at which the pump is to be installed. This depth must be above the perforation interval, so the depth was chosen depending on the depth of tubing of well which equal to 1910 meter.

Design production rate: Desired flow rate through the pump in stock-tank units. This value is selected depending on bubble point pressure (2105 psi) and operating envelope area which specifies values of reservoir pressure, drawdown limit, erosional velocity ratio maximum and inversion point for stable tubing production, as shown in the yellow rectangle in Figure (8). The design flow rate has been selected as 3750 STB/D in this value was selected depending on operation envelope area. After inputting the required data for ESP design the software will suggest the suitable pump type. The results have been summarized in the Table (9). Figure (9) showed the performance curve for the pump.

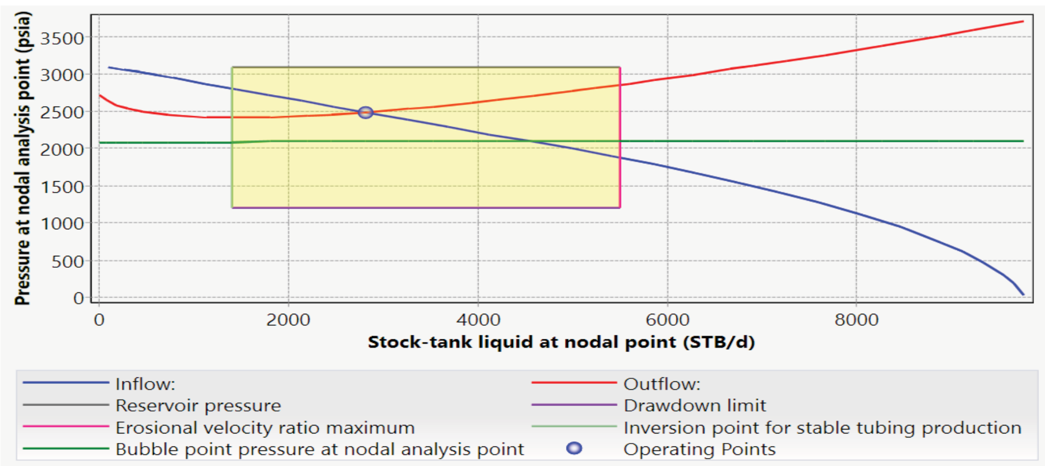

Fig. (8) The performance curve of pump for well (NS-Y)

Table (9) Summary results of the pump selected for well NS-Y

Parameters	Value
Manufacturer	XPC
Model	G5800EZ
Diameter, in	5.13
Series	540
Min. Flow, STB/D	3834
Max. Flow, STB/D	6902
Operating frequency, Hz	60
Operating speed, RPM	3450
Number of stages	31
Intake pressure, psi	2165
Intake liquid rate,bbl/d	4930
Intake gas rate, MMSCF/d	0
Efficiency, %	71
Power, HP	36
Head, m	299
Differential pressure, psi	316
Discharge pressure, psi	2482
Fluid temperature rise, F	1.1

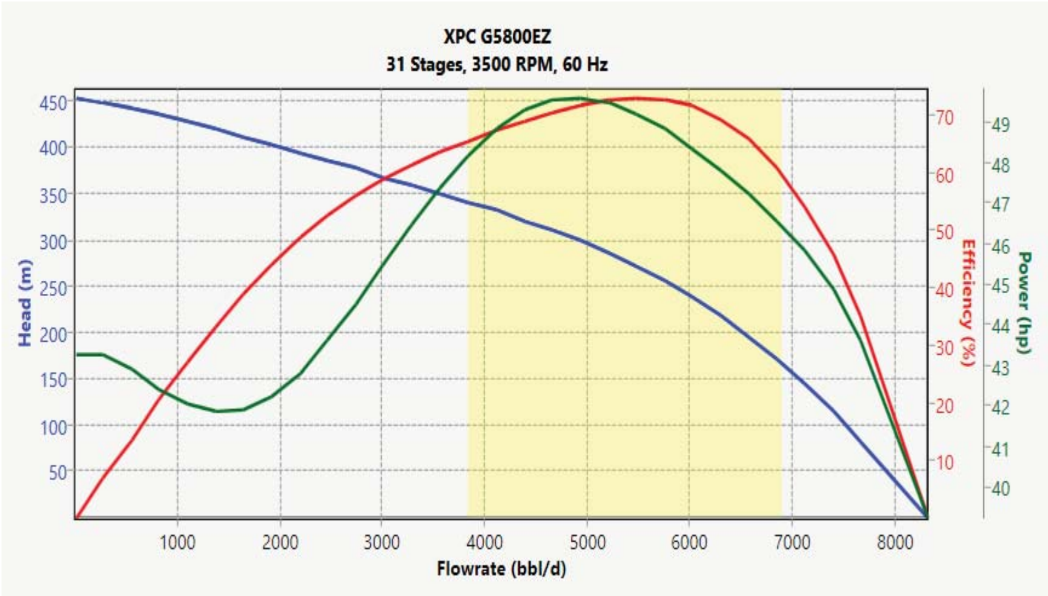

Fig. (9) The performance curve of pump for well (NS-Y)

Results:

1- The results of reservoir pressure decreasing showed that production rate after installation of the gas lift system was increased from 3109 STB/D at natural flow to 3931 STB/D at reservoir pressure of 3120 psi, and increased from 1917 STB/D to 3198 at reservoir pressure of 2750 psi. While, the ESP increases the oil production rate from 3109 STB/D to 3754 STB/D at reservoir pressure 3120, and from 1917 to 2800 STB/D at reservoir pressure 2750 psi, this results are listed in Tables (10 and 11), and showed in Figures (10 and 11). All values of flow rate and P_{wf} have been calculated by PIPESIM software based on the principle of nodal analysis. The P_{wf} in ESP case was higher than the Gas lift case because the design flow rate has been selected at P_{wf} above Bubble point pressure (2105 psi). Finally, the Gas lift system has achieved quantities of production rate was more than ESP at different reservoir pressure as shown in Figure (12).

Table (10) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, (Gas lift)

Reservoir pressure (Psi)	Liquid flow rate (STB/Day)	Bottom hole pressure (psi)
3120.8	3931	2237
3050	3791	2197
2950	3591	2142
2850	3393	2087
2750	3198	2030

Table (11) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, (ESP)

Reservoir pressure (Psi)	Liquid flow rate (STB/Day)	Bottom hole pressure (psi)
3120.8	3754	2277
3050	3583	2244
2950	3335	2200
2850	3074	2159
2750	2800	2120

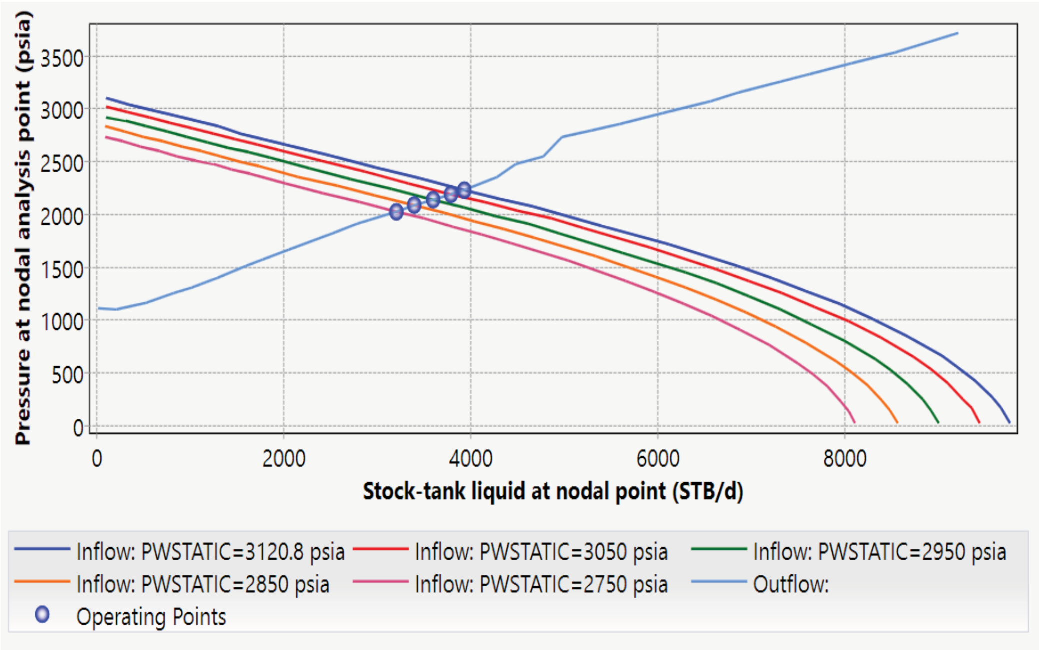

Fig. (10) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi with Gas lift system

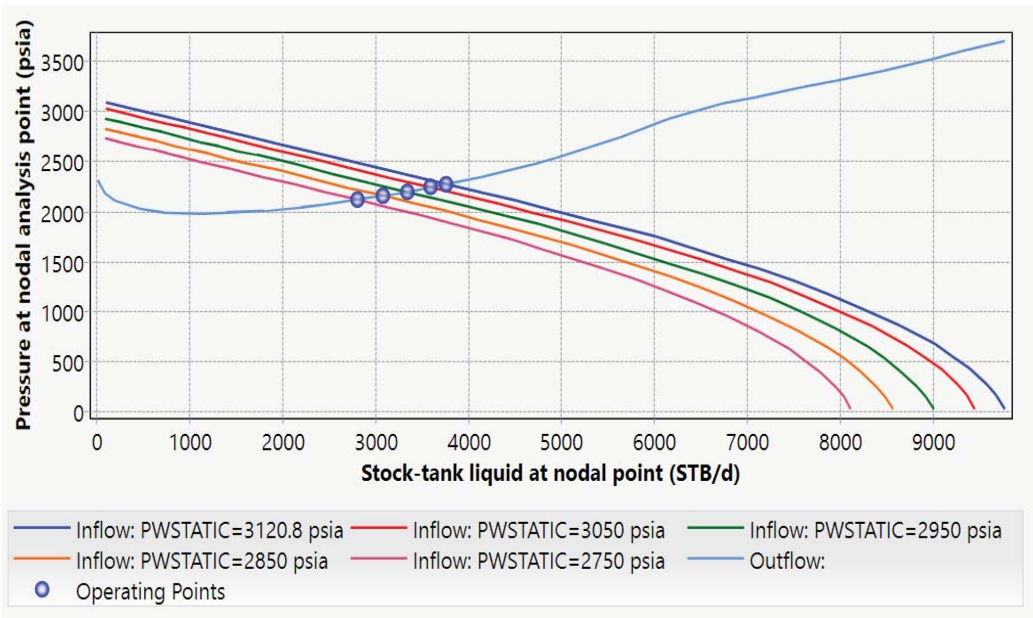

Fig. (11) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi with ESP.

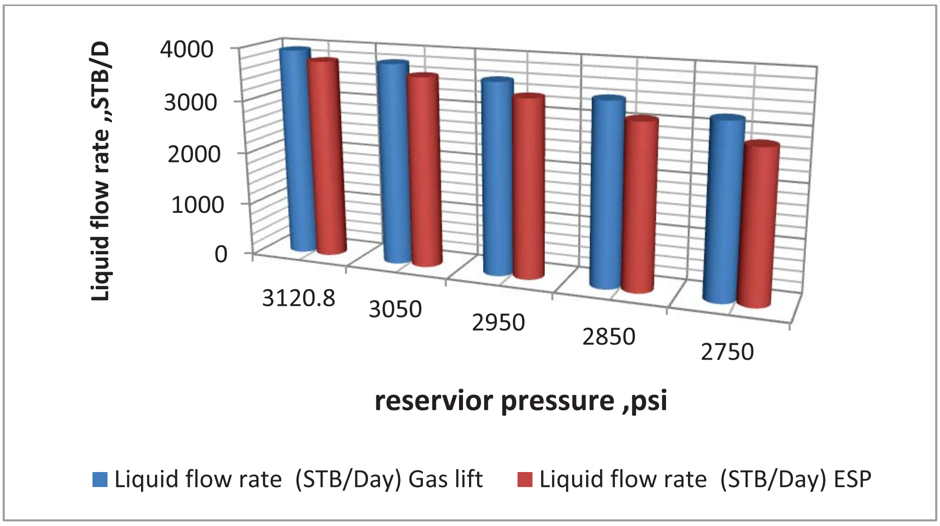

Fig. (12) Comparison of production rates between Gas lift and ESP at different reservoir pressure.

2- The impact of water cut demonstrates that ESP system achieved higher production rates than Gas lift system at water cut 0 and 10%, while the gas lift system achieved higher production rates than ESP system at water cut 20%, 30%, 40% ,50% and 60% as given in Tables (12, 13) and Figures (13, 14 and 15).

Table (12) Summary Results well (NS-Y) at water cut (0 – 60%), (Gas lift)

Water cut %	Liquid flow rate (STB/Day)	Bottom hole pressure (psi)
0	4022	2216
10	3989	2224
20	3955	2231
30	3921	2239
40	3884	2247
50	3845	2256
60	3805	2265

Table (13) Summary Results well (NS-Y) at water cut (0 – 60%), (ESP)

Water cut %	Liquid flow rate (STB/Day)	Bottom hole pressure (psi)
0	4089.603	2201.788
10	4028.851	2215.44
20	3920.217	2239.852
30	3789.334	2269.264
40	3601.29	2311.521
50	3362.783	2365.118
60	3087.65	2426.946

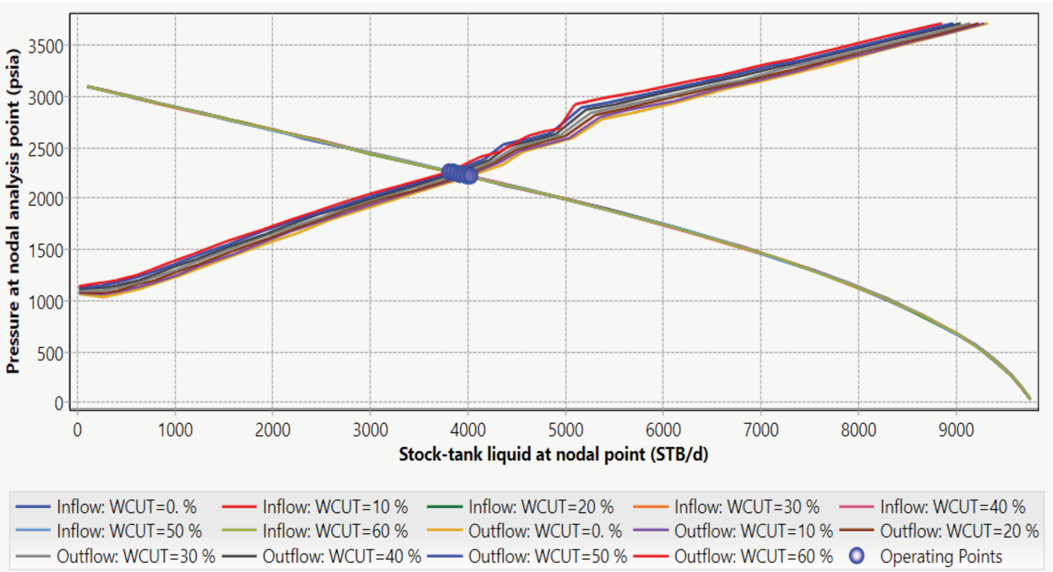

Fig. (13) Nodal analysis, sensitivity for well (NS-Y) at water cut (0 – 60%) with Gas lift system

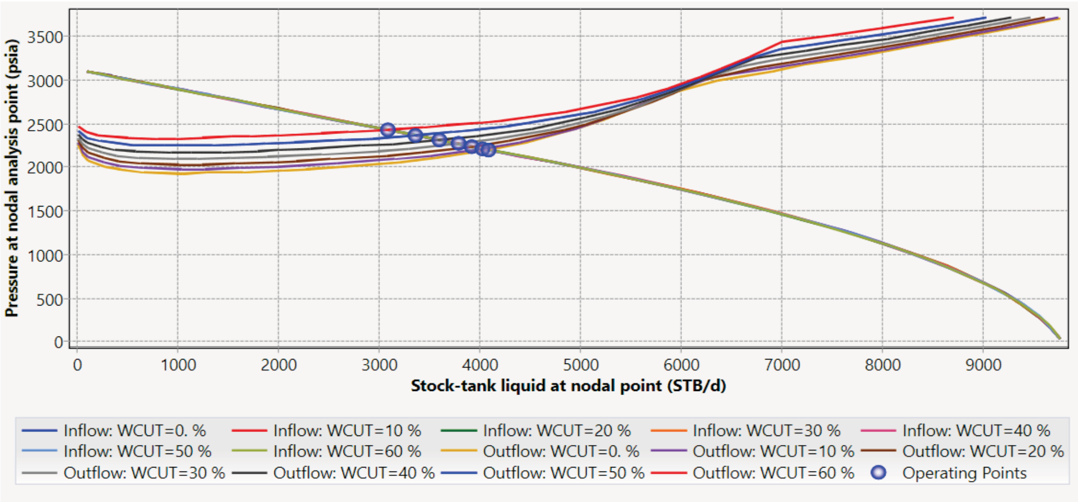

Fig. (14) Nodal analysis, sensitivity for well (NS-Y) at water cut (0 – 60%) with ESP system

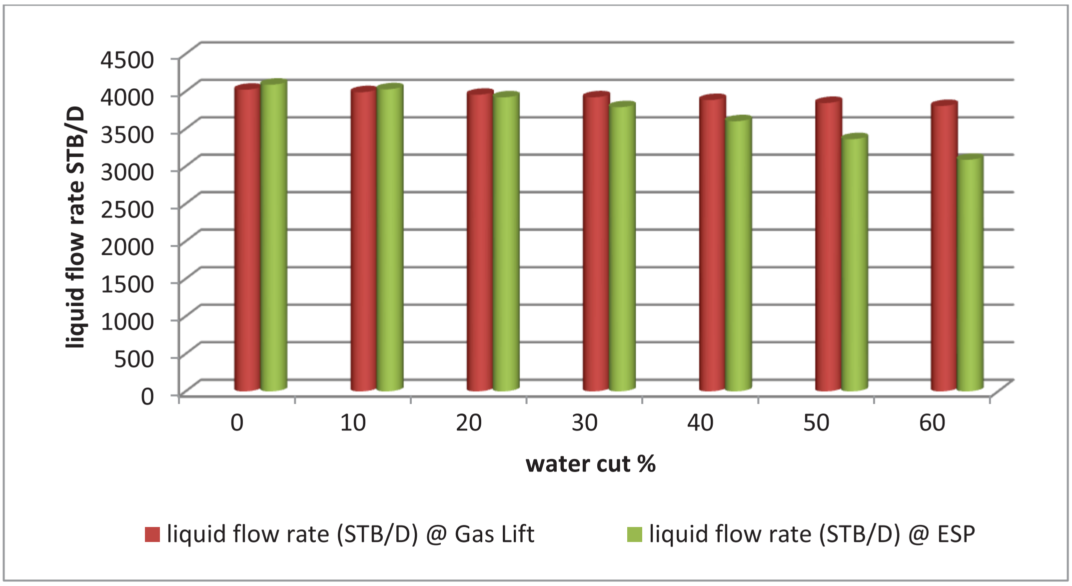

Fig. (15) Comparison of production rates between Gas lift and ESP at different water cut

Conclusions:

1. pressure gradient matching (Duns & Rose) was the best correlation for the pressure drop in wellbore for well NS-Y.

2. The optimum surface injection pressure was found to be 1800 psi and optimum Gas injection rate was 3 MMSCF.

3. It was found that the pump model suitable for well NS-Y (XPCG5800EZ) with efficiency of 71%

4. The comparison of gas lift system and ESP production rates showed that the gas lift system the offers highest oil production rate at different conditions of reservoir pressure and water cut.

Nomenclature:

ESP : Electric submersible pump.

CHP : Casing head pressure or surface injection pressure, Psi

Qgi : Gas injection rate. MMSCF/D

QL : Liquid flow rate, STB/Day

GOR : Gas oil ratio, %

Pr : Reservoir pressure, Psi

WC : Water cut

RMS : Root mean square

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